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# MENTAL STATES AND NON-LINEAR OSCILLATIONS

## ELECTROMAGNETIC RADIATION LABORATORY, AFCRL

Parallels between non-linear oscillation phenomena and E.E.G. (Electroencephalogram or brain wave) observations have led Dr. Edmond Dewan of AFCRL to suggest a model to explain certain mental disorders, particularly that of epilepsy. The model is also relevant to other mental phenomena -- awareness of the flow of time, hypnosis, and musically induced emotion.

Dewan's theoretical study has implications to that aspect of biophysics concerned with constructing electronic analogies of certain neural functions. The investigation is designed to shed light on electrical events taking place in the brain during various types of paroxysmal seizures. The model is one which regards the brain as a network of coupled non-linear oscillators, an idea recently explored by Norbert Weiner of MIT.

Dewan applies this idea to epileptic seizures. One might ordinarily think that these seizures are the result of some catastropic mental instability. Dewan points out however that epilepsy involves excessive stability. This happens when the coupled non-linear oscillators become too tightly locked together. There is then an "harmonic entrainment" or pulling together of oscillations of the same frequency. When this is the case, then there is also the possibility of "subharmonic" and "superharmonic" entrainment. This means that certain oscillations can lock together in phase with subharmonics and superharmonics of a driving frequency. Petit mal -- the less severe case of epilepsy in which sometimes neither the subject or the observer is aware of the seizure -- may result from such a locking-in phase involving subharmonics and superharmonics.

Epilepsy can be induced by various mechanisms -- electric shocks, flickering lights, and drugs. Sensory inducement, as in the case of the lights flickering at certain frequencies, has been experienced by many persons in the form of disorientation. It can occur when strong sunlight is viewed through revolving propeller blades, or among the leaves of trees when driving.

Dewan's study has led him to suggest a number of experiments, designed to learn more of the gross electrical properties of the brain. Some of these experiments involve measuring the effects of certain drugs upon "phase lock" and comparing of E.E.G. data with correlated mental events. One of the interesting things about this theory is that it makes definite predictions and hence is easy to test.

The focusing of attention, the phenomenon of consciousness and perhaps even "multiple consciousness" of the Jekyll and Hyde type may all be related to various aspects of the oscillation model. All of these possibilities remain to be tested experimentally.

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*The continuing goal of the "OAR RESEARCH REVIEW" is an attempt to satisfy the information needs of both the scientist and the nonscientist decision maker, since we feel each is of importance.*

*It is inevitable that many decisions concerning basic research, from the budget that supports it to the manner in which it is fed into applied research and development activities, are made by people who are not scientists.*

*We believe that it is imperative that these people be informed about research in progress, and understand something of its potentialities. It is equally imperative that the scientist be kept up to date on research projects occurring within his areas of interest. Each time this publication prevents needless duplication of effort by informing a research scientist of new knowledge discovered, it will have achieved an important contribution of the Free World's scientific resources.*

*Those of you among our readers who feel a need for further information about a topic covered in any issue are urged to contact the author or originating laboratory direct. Addresses for use on such occasions are shown on inside back cover of this issue.*

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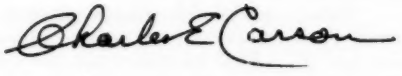
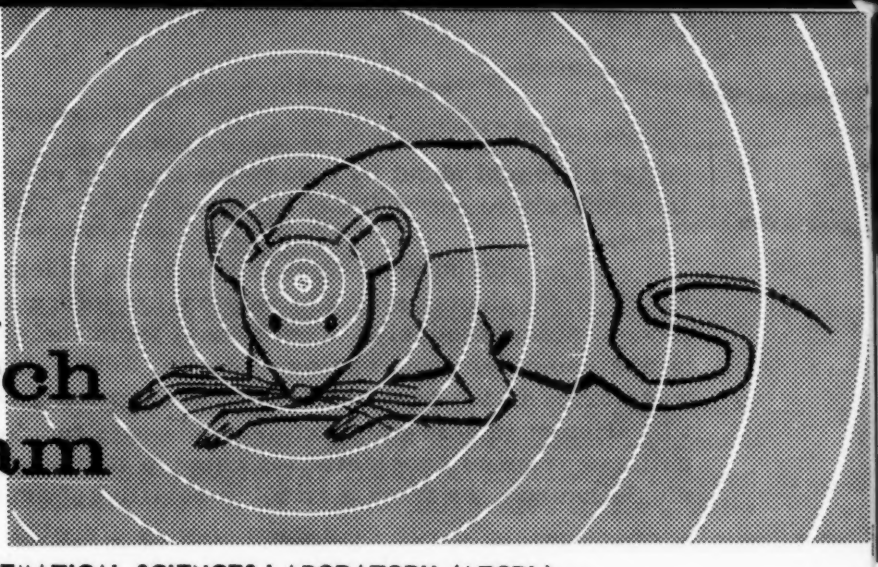


CHARLES E. CARSON
Colonel, USAF
Deputy Commander

# new neural research program



## COMPUTER AND MATHEMATICAL SCIENCES LABORATORY (AFCRL)

AFCRL will soon establish a new research effort for investigating the neural structure of mammals. Laboratory facilities are now being planned, with the key instrumentation being a computer permitting the direct processing of electrical signals from the brains of mammals. This computer, known as the Linc computer, is a modification of a Lincoln Laboratory prototype. It was adapted for AFCRL by Lt Charles E. Molner.

Theodore Kalin will head the new group. The group will concentrate on the analysis of the waveforms from the brains of animals --- primarily rats. Such waveforms have been observed in mammals since 1875, but few meaningful patterns have emerged. Only recently has progress been made and this has been limited. An early difficulty was the time required to manually reduce the data.

Computer reduction of data has made the job easier but, when done subsequent to the experiment, experimental problems still remain. All too often when the experiment is repeated, the results do not agree with earlier data because the particular animal, the particular experimenter or the particular conditions differ from the first experiment. It is the goal of the AFCRL group to concentrate on experiments that can be strictly repeatable. The Linc computer, now being assembled, will help the AFCRL group to achieve this.

The AFCRL computer will permit the direct processing of waveform data while the experiment is in progress. The electrodes implanted in the animal's brain will be linked through an amplifier directly to the computer. If the investigator notices some anomaly in the wave

pattern brought about by some stimulus, he can reapply the stimulus immediately to see if the pattern reoccurs.

The computer, which is now being assembled at AFCRL, can handle eight channels of information (or information from eight electrodes) simultaneously. The signals from the electrodes are converted by the computer from analog to digital form. Most of the work done on waveforms in the past have considered gross areas of the brain. AFCRL will attempt to correlate patterns obtained from gross areas with the patterns from microelectrodes capable of measuring the output from a single neuron, or from a small population of neurons.

One of the first experiments conducted by AFCRL will be a study of the visual cortex. AFCRL will study patterns caused by brief, low intensity stimuli, such as that from a low-intensity strobe light, to measure the expansion outward within the brain's neural structure of the waveform created by this light. The pattern of expansion may furnish clues to the brain's overawing capability to retrieve and recall information. The expanding wave moving outward from the visual cortex stimulates other centers and these, in turn, influence still others in a hierachical and entangled web of activity. These mechanisms have enormous complexity.

Our understanding of the physical, chemical and mathematical properties of the brain is at just about the level that we would expect to find in a 19th Century physicist confronted with an IBM 7090 computer and asked to explain its operation in order to build another one. This physicist, in attempting to construct some conceptual model of the computer, would be forced into error by adopting the conventional physics and mathematics of his day. It may be well that present physical and mathematical concepts inhibit insight into the subtle mechanisms of the brain.

Kalin, who heads the group at AFCRL, was former Chief of AFCRL's Computer and Mathematical Sciences Laboratory before he took a two-year's leave of absence to work with neurophysiologists at the Massachusetts General Hospital. Through his work on the neural systems of mammals, he gained a knowledge and experience in neurophysiology to match that of his primary background in electronic computing systems.

It is expected that research personnel at the Massachusetts General Hospital, the Lincoln Laboratory and from other organizations will be invited to use the AFCRL facility to conduct experiments that compliment those of AFCRL.

# GRAVITY WAVES

JOSEPH E. DUVAL, Lt Colonel, USAF, Nuclear Physics Division (AFOSR)

The existence of gravity waves, i.e., oscillations in a gravitational field analagous to electromagnetic waves in an electromagnetic field, has been predicted from the General Theory of Relativity proposed by Professor Albert Einstein in 1916. The theory indicates that a gravitating mass such as a double star or spinning rod one meter long radiates about $10^{-30}$ ergs per second when rotated rapidly about a transverse axis. A great amount of theoretical effort has been expended on the problem of gravitational radiation, but very little experimentation has been conducted thus far. Professor J. Weber of the University of Maryland is doing both theoretical and experimental research on the generation and detection of gravity waves under grants from the Air Force Office of Scientific Research and the National Science Foundation. He is building a detector with which he will search for gravity waves from interstellar space. In addition, he is constructing a generator and expects shortly to demonstrate that gravity waves can be produced and detected in the laboratory.

The detector is one and one-half ton aluminum cylinder housed in a vacuum chamber. Gravitational radiation incident on the cylinder is expected to cause it to vibrate. Piezoelectric crystals are used to convert displacements of the end faces of this cylinder into electrical signals. Relative displacements of the cylinder end faces of about $10^{-15}$ centimeters have already been detected, and when the instrumentation is completed, detection of displacements of $10^{-16}$ centimeters is anticipated. Professor Weber intends to search for gravity waves from space in the kilocycle per second frequency range and predicts that his apparatus will be able to detect gravitational flux with a power spectrum of about $10^{-4}$ ergs per square centimeter per second per cycle.

The generator is an aluminum cylinder 8 inches in diameter and 6 feet long, also housed in a vacuum chamber. A driving force with a one ton amplitude causes the cylinder to vibrate at 1650 cycles per second. The force is applied by piezoelectric crystals fastened to the cylinder and stressed electrically to give the desired force.

The two cylinders are isolated from each other by being suspended in vacuum chambers, which are mounted on insulators to isolate them from

earth vibrations. Since this eliminates accoustical and direct coupling, it is expected that interactions between the cylinders will be through the gravitational field. This interaction is postulated to occur through the "near" part of the gravitational field, analagous to the coupling of two electrical circuits by induction, rather than through the radiation portion of the field. The gravitational radiation transmitted from the generator to detector, in a manner corresponding to electromagnetic radiation transmitted from a radio antenna to a receiver, is too weak to be detected. However, if the detector proves to be sensitive to perturbations of the near field, then one may expect it to be sensitive to gravitational radiation from interstellar space, since this radiation is expected to be of greater intensity than that from the vibrating cylinder.

The value of this investigation lies not in the possibility that gravity can be harnessed in a manner similar to electromagnetism but in the fact that by solving some of the problems associated with gravity, we may learn something new about the universe which will have a more direct application to Air Force problems that are not even anticipated at the present time.

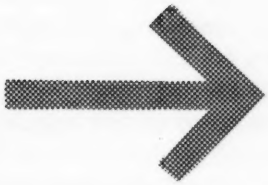
# experimental anomaly

### IONOSPHERIC PHYSICS LABORATORY (AFCRL)

Interesting (if not scientifically useful) data was recently reported on an AFCRL experiment in which an Astrobee 1500 rocket was fired aloft to measure electron density. On the rocket ascent up to 150 km, the electron density measurements compared with previous measurements. From about 160 km, however, electron densities decreased very rapidly until at peak altitude of 265 km the values measured were the same as those obtained at 95 km. On descent, from 265 km to 160 km, the electron densities were only about 16 percent of expected values. But from 100 km down, the ascent and descent data were the same.

Interpretation of these puzzling results led to the conclusion that the rocket fuel valves, which were still open after burnout, continued to let some residual propellant escape throughout the flight. When the diffusion velocity of the propellant reached a value greater than the rocket velocity, the ambient electron density around the antenna was reduced by an attachment process. Hence, the low values recorded.

# SOME ASPECTS OF PROPULSION USING SUBMICRON SIZED PARTICLES



EVERETT D. STEPHENS,
Thermomechanics Research Laboratory (ARL)

It is axiomatic that a very small thrust exerted on a body can produce the same velocity as a large thrust if the very small thrust is applied for a proportionately longer period of time. For space applications outside the atmosphere of the earth, low-thrust techniques become attractive for short-range missions such as earth-to-moon and earth-to-Venus or Mars flights.

One of the methods for producing very small thrusts involves the acceleration of very small charged particles (ions and colloids). Dr. D. B. Langmuir and Dr. V.E. Krohn of Space Technology Laboratories, working under an ARL contract, have been exploring various techniques of charging and accelerating submicron sized particles.

The basic components of the source system used by Langmuir and Krohn consist of a reservoir of liquid, a source tube for expelling the liquid, a high vacuum region surrounding the source, a region of controlled pressure above the liquid reservoir, and a positive high voltage supply. The reservoir pressure and the high voltage control the flow of liquid through the source tube.

The thrust obtainable from this process may be expressed as

$$F = \frac{0.318\ P}{\left[\frac{Q\ V}{M}\right]^{\frac{1}{2}}}$$

where the thrust F (pounds) is a function of the power P (watts), the charge-to-mass ratio Q/M (coulombs/kilogram), and the accelerating voltage V (volts). The corresponding specific impulse $I_{sp}$ (sec) is

$$I_{sp} = 0.144\left[\frac{QV}{M}\right]^{\frac{1}{2}}$$

The charging of small particles (colloids) with masses of $10^2$ to $10^6$

times those of simple monatomic or polyatomic ions provides one means of achieving higher thrusts since the charge-to-mass ratios Q/M may be $10^{-2}$ to $10^{-4}$ of those ordinary ions. However, the $10^2$ to $10^4$ increase in thrust is obtained only at the expense of a proportionate decrease in specific impulse $I_{sp}$ providing power P is kept at the same level.

The techniques of particle generation and charging involve many problems. It is highly desirable to obtain uniform particle size and uniform charge-to-mass ratio since the thrust obtainable falls off if not achieved. Charge neutralization of the expelled beam of charged particles is also a major problem.

To date the investigation undertaken by Drs. Langmuir and Krohn has concentrated on liquid metals and organic liquids as the expellant materials. Droplets of a eutectic mixture of lead and bismuth generated and expelled from a 0.003 inch inside diameter tube at an accelerating voltage of 5 kilovolts varied greatly in size. It was found that most of the mass was carried by large droplets (colloids) having a low charge-to-mass ratio (less than 10 coulombs/kilogram) and that the charge was mainly carried by metal ions with a charge-to-mass ratio greater than 1000 coulombs/kilogram. The charge carried by the metal ions was on the order of 50 times that carried by the droplets. As pointed out previously, this condition represents an undesirable spread of charge-to-mass distribution.

Organic liquids appeared to be much better with regard to charge-to-mass distribution. For example, a solution of glycerol with antimony trichloride as an additive yielded a Q/M ratio of between 180 and 330 coulombs/kilogram without accompanying ion currents of significant magnitude. Charge-to-mass ratios as high as 470 were produced with increases in the additive (up to seven percent by weight) which increased the electrical conductivity of the expellant. It was found that the conductivity of the liquid was of prime importance in determining whether charged droplets could be produced without a large number of ions accompanying them and that the conductivity was very important in determining the charge-to-mass ratio of the droplets.

A theoretical study of the limitations of the maximum charge that a droplet of a given size can carry (involving a combination of the Rayleigh limit and the ion limit) was performed and experimentally confirmed for a number of liquid metals.

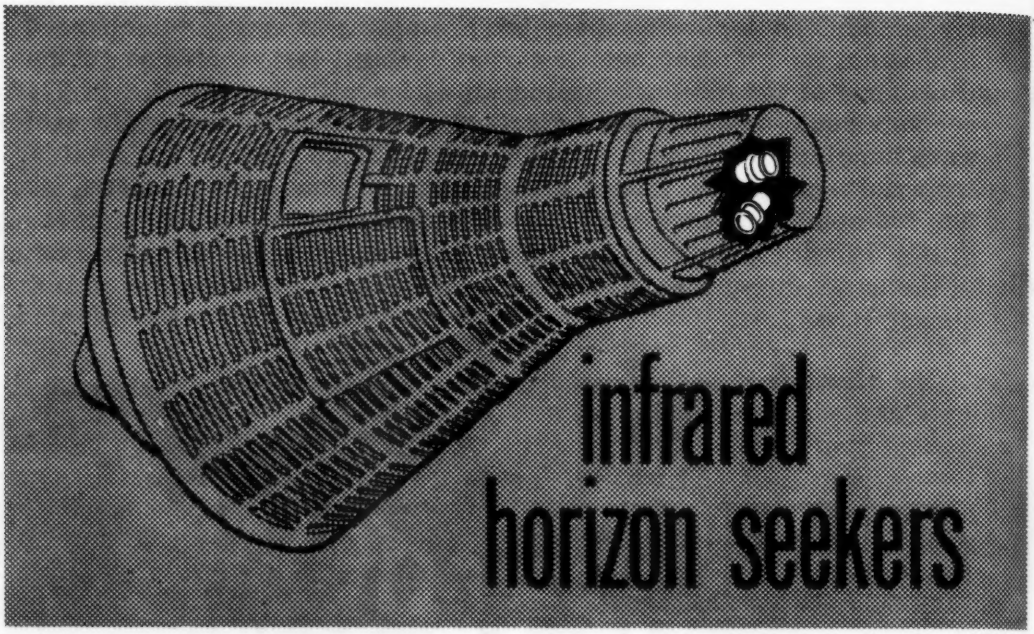
Although many interesting effects have been discovered during

the course of the present work, the possibility of using a source of the type described does not appear too promising to supply the charged propellant for an electrostatic thrust device. With a charge-to-mass ratio Q/M of 470 coulombs/kilogram, a specific impulse $I_{sp}$ of 2000 seconds could be achieved if glycerol containing 7% antimony trichloride were accelerated through 430,000 volts. Since the current obtained from a single source tube was approximately one microampere, about 100,000 source tubes would be required to produce one pound of thrust at this specific impulse. In addition, great improvement would be needed in the uniformity, the reliability, and the operating lifetime of individual source tubes.

**PHOTOCHEMISTRY LABORATORY (AFCRL)**

The highest reentry speed ever obtained for a man-made object -- about 12 km per second -- was achieved in May in an experiment designed by AFCRL scientists. The reentry body was a steel pellet of about 3/4 inch diameter which was propelled downward from a height of about 200 miles. The pellet became an artificial meteor, creating a bright trail visible in Virginia and North Carolina. A six-stage solid- fueled NASA rocket, Trailblazer 2, was used in the experiment. The last four stages were used to propel the artificial meteor downward. The rocket was launched from Wallops Island.

The purpose of the experiment was to determine the luminosity and ionization of entering bodies as a function of their size and mass. Measurements were made by radar and by Baker Super Schmidt cameras. The artificial meteor was the second such meteor created by AFCRL. The first experiment took place in April 1961, and obtained a maximum reentry speed of 10 km per second.




**THERMAL RADIATION LABORATORY (AFCRL)**

The infrared horizon seekers of the second Mercury capsule may have contributed to the instability of the capsule's automatic control system. This possibility was suggested by AFCRL scientists studying infrared phenomena. Horizon seekers used on the Mercury capsule (and for Tiros, Nimbus and other satellites requiring a high degree of stabilization), operate by detecting the line where the cooler sky meets the warm edge of the earth.

For the Mercury capsule, lead sulfide detectors were used. Lead sulfide detectors are broad-band, and the detectors on the Mercury capsule may have been degraded by the water vapor content in the atmosphere. Because water vapor in the atmosphere varies, the detector may see the horizon at a different angle as it passes from the ocean to a dry land mass. The difference in water vapor content could alter the tilt angle of the capsule by a degree or so. Ideally the tilt angle should not vary more than a fraction of a degree.

Anticipation of this problem led AFCRL to begin work on a narrow-band infrared detector centering on the strong carbon dioxide absorption band in the infrared region. This band is of interest because carbon dioxide is rather uniformly distributed in the atmosphere. Thus the horizon seeker will not be unduely affected by varying atmospheric constituents.

# STRATOSPHERIC humidity experiment

## METEOROLOGICAL DEVELOPMENT LABORATORY (AFCRL)

Considerable controversy has been generated by apparent disagreement in results obtained by British and American investigators of the distribution of humidity in the stratosphere. The British have consistently found very little water vapor, while the American experiments have indicated considerable variability in atmospheric water vapor content exists. (See story, "Infrared Horizon Seekers", for implications of water vapor content.)

An attempt to resolve some of the apparent discrepancies and simultaneously obtain an estimate of the accuracies of several types of humidity sensor devices is planned by AFCRL in September, 1962. This experiment will take place at 85,000 feet in Minnesota.

Several carefully calibrated hygrometers will be carried aloft by balloon. Included will be two types of microwave refractometers, a dew-point hygrometer and several electrolytic hygrometers such as the aluminum oxide and carbon humidity element.

As standards, two gravimetric devices will be compared, a freeze-out device designed by Goldsmith and Parham of the United Kingdom Atomic Energy Authority and a molecular-sieve apparatus developed by AFCRL.

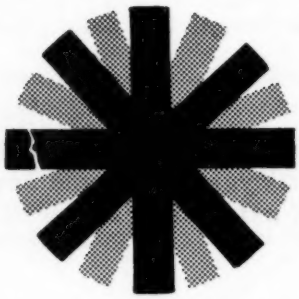
The Goldsmith-Parham apparatus collects water vapor and carbon dioxide by pumping a sample of air through a liquid nitrogen cooled coil which traps the water vapor and carbon dioxide. After recovery of the device, the amounts of these materials collected will be determined. The amount of air sampled is ascertained from the quantity of carbon dioxide condensed. (The experiment assumes that this atmospheric constituent is present in constant proportions throughout the atmosphere.) Several experimental investigations with this apparatus have been conducted in

England and appeared to yield acceptable data but no comparisons were possible.

The molecular-sieve is a synthetic zeolite (in this case calcium-aluminum-silicate) which is a highly effective absorber of water and carbon dioxide. AFCRL investigations of non-destructive regeneration of the sieve indicates that accuracies within two percent are possible. It is believed that even greater accuracies may be achieved by destructive regeneration. Two checks of the volume of air sampled will be used --- calibrated flow-meters and a carbon dioxide air volume determination similar in principle to the British method.

The least that can be expected from a successful experiment is the determination as to whether or not there is a discrepancy between the British and U.S. gravimetric techniques. Further, information about the accuracies of the various hygrometers is expected to shed valuable light upon techniques used for measuring atmospheric humidity and the accuracy of microwave refractometers to these altitudes. An important by-product of this instrumentation research will be very reliable stratospheric humidity data.

## design for FAILURE



ELECTRONIC MATERIAL SCIENCES LABORATORY (AFCRL)

Failures of electronic equipment and components must be classed along with death and taxes. They are inevitable. Over the past decade, Walton B. Bishop of AFCRL has written widely on problems of electronic systems reliability. In his most recent paper, he concludes that since failures are inevitable we should specifically design equipments and components so that they will fail.

The key qualification to his thesis is that we know within reasonable limits just when we can expect an equipment to fail. If we can design failure within specified time periods, then we may be able to avoid unexpected failures and their potential catastrophic results. Designing for a specific time of failure does not necessarily reduce reliability, and at

the same time eliminates uncertainty -- and overspecification with the unnecessary costs that attend overspecification.

In his paper, Bishop introduces the concept of "failure modules." Paradoxically, reliable equipment can be built of "failure modules" if either: 1) module failure has a high probability of failing with a known time interval, or 2) provision is made for failure detection and automatic replacement.

Knowledge of the source of failure of each module of a piece of equipment (modules being of whatever size we choose), can be used to exercise control over the time when failures occur. This process of designing for a failure when we want it to occur turns out to be easier than designing for no failures during some specified period. The parts of a module that are capable of lasting ten times as long as the part that fails are greatly overdesigned and in general more expensive than they need be. The strongest part of an equipment is so much stronger than the weakest part that weakening the more reliable elements a little will not change the overall reliability of the equipment to any significant extent.

NASA, through Jet Propulsion Laboratories, has asked AFCRL to design a mass spectrometer to be incorporated in future Mars and Venus probes. The request resulted from AFCRL's long and unique experience in spectroscopic techniques for measuring the constituents of the atmosphere. (Photochemistry Laboratory)

AFCRL this summer will join NASA in a cooperative series of experiments to directly sample noctilucent clouds. Noctilucent clouds are faintly luminous, very high clouds of unknown origin which occur at night. These clouds occur only in certain regions of the auroral zone for a short period during the summer months. Four Nike-Cajun sounding

rockets will be used. Rocket payloads will include a nuclear emulsion pack and an electrostatic analyzer to make energetic particle measurements. (Photochemistry Laboratory)

The T-3 Ice Island Camp, established by AFCRL on a floating ice island in the Artic and used by AFCRL scientists over a 10-year perio has been turned over to a Navy research team. First occupied in 1952, th ice island was used for a host of AFCRL scientific investigations. The island went aground in May 1960, but freed itself in early 1962. (Terrestrial Sciences Laboratory)

Mercury Flights: AFCRL, during both the Glenn and Carpenter flights, furnished index of refraction data at the time of launch. Such data is essential if the ground tracking stations are to know the true location, as against the apparent location, of the capsule, and is therefore essential during the launch and insertion period. A refractometer was used at Cape Canaveral by personnel of the AFCRL Meteorological Development Laboratory to record the data..... The AFCRL-developed (Meteorological Development Laboratory) Arcus-Robin rocket for measuring atmospheric density and wind conditions at extreme altitudes was used by NASA prior to the Carpenter flight..... Also furnished by the AFCRL Sacramento Peak Observatory during the period were twice-daily predictions on the probability of dangerous solar showers occurring at the time of the flight.

Three Aerobee 150 rockets, carrying AFCRL experiments, will be launched at White Sands in June. Two of these are designed to measure solar radiation in the extreme ultraviolet region (250 to 1300 Angstroms). The vehicles, with payloads of 230 pounds will reach 135 miles. From these experiments, AFCRL hopes to learn more about the intensity of UV radiation and how it is absorbed by the earth's atmosphere. Dr. Hans Hinteregger of the AFCRL Photochemistry Laboratory, designed the experiment. The third Aerobee 150 will measure the intensities of, and to some extent, the spectral distribution of X-rays from the lunar surface and will survey the sky for other possible sources of soft X-radiation. The Aerobee, with a 125-pound payload, should attain a peak altitude of 155 miles. During ascent, three panels will be released to expose sensing elements. Project scientist is Lt. John Salisbury of the AFCRL Research Instrumentation Laboratory.

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